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Textile Dyebath Reconstitution and Reuse

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TEXTILE DYEBATH RECONSTITUTION AND REUSE

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16. ABSTRACT The paper discusses the recent demonstration of the application of an important wastewater recycle technology (reconstitution and reuse of spent dyebath solutions) to the textile industry. After several months of bench and pilot testing, the technology was demonstrated under production conditions for 2 weeks at a major carpet mill in the Southeast. Of the 13 batch production units (becks), 2 were used in the demonstration. The project showed how several technical problems, encountered using dyebath reconstitution at a wide variety of textile mills, could be overcome, including: selecting product styles and shades that can be incorporated in a dyebath reuse scheme; reformulating dye recipes to use a single group of dyestuffs to dye many shades; reusing dyebath on a portion of production within the normal production schedule; producing high-quality product with recycled dyebaths; and adapting dyebath reuse procedures to the mill's standard dyeing procedures. The environmental benefits to the mill were significant, even though dyebath reuse was not practiced optimally: pollutant and water use were reduced 25-50%; dyebath reuse was shown to be economically attractive, with an 18-month payback projected for the mill; and a capital investment of $240,000 and a yearly operating cost of $5,000 could save $180,000 per year if half of the mill's becks were converted to reuse.

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a. DESCRIPTORS	b. IDENTIFIERS/OPEN ENDED TERMS	c. COSATI Field/Group
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Textile Industry	Stationary Sources	11E
Dyeing	Dyebaths	13H
Circulation	Reconstitution	14G
Waste Water		
Water Treatment		

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TEXTILE DYEBATH RECONSTITUTION AND REUSE

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INTRODUCTION

The finishing of textile products results in the discharge of over 100 billion gallons* of wastewater annually in the United States. It is estimated that about 80 percent of textile finishing mills discharge their wastewater to publicly owned treatment works (POTW). Most of this wastewater receives either no treatment or only primary treatment, such as settling, screening, equalization, or neutralization, prior to discharge to the municipal sewers.

The major textile finishing operations include fiber preparation (desizing, scouring, mercerizing, bleaching), fiber coloring (dyeing, printing), and functional finishing. Wastewater results primarily from the preparation and coloring operations.

Many wastewater recycle/reuse technologies are available to allow reuse of these wastewaters. Reference 1 provides a detailed description of such recycle/reuse technologies. One of these technologies, dyebath reconstitution and reuse, was selected for further investigation as it appears to offer significant environmental benefits and substantial cost savings to the industry, and it also has the potential for widespread use within the industry.

TEXTILE DYEING

The vast majority of textile products are colored by dyeing. In 1980, approximately 7.8 billion pounds of fibers were dyed. To accomplish this dyeing, 171 million pounds of dyestuffs and 1.28 billion pounds of additives (auxiliary chemicals) were used. Most

*The units of measurement most familiar to the projected readership of this paper have been maintained. See Unit Conversion Table.

auxiliary chemicals do not exhaust during dyeing and are thus discharged with the dyeing wastewater. Dyestuffs, however, generally exhaust to over 90 percent during dyeing. Assuming a 95 percent exhaustion rate, about 8.5 million pounds of dyestuffs are discharged annually in dyeing wastewater.

Dyeing can be performed using either continuous or batch processes. Approximately half of the textile fibers dyed in the U.S. are batch dyed. Certain products, such as knit fabrics, hosiery, and yarn, are almost exclusively dyed using batch processes. Large amounts of carpet and some woven fabrics are also batch dyed. Batch dyeing remains popular due to its flexibility, short-run capability, and ease of control. Batch processes, however, are generally inefficient in their usage of water and auxiliary chemicals.

In a typical batch dyeing operation, water usage as dye liquor ranges from 1 to 5 gallons for each pound of fibers dyed. Auxiliary chemicals and dyes are added to this dye liquor. Auxiliary chemicals can include exhaust agents, leveling agents, buffers and pH control chemicals, retarding agents, wetting and dispersing agents, carriers, softeners, lubricants, penetrants, among many others. The total amount of auxiliary chemicals added will vary depending on the fiber and dyestuff types, but will generally range from a few percent of the fiber weight (2 or 3 percent o.w.f.) to as much as 50 percent where high concentrations of exhaust agents are required. Dyestuff quantities are generally a few (less than 4) percent of the fiber weight. Following the addition of auxiliary chemicals and dyes, the dyebath temperature is raised to the desired dyeing temperature and held until dyeing is complete and a level dyeing is achieved. The exhausted dyebath, now containing only a few percent of the original quantity of dyestuff but still most of the auxiliary chemicals, is dropped, and the dyed product is rinsed with fresh water.

DYEBATH REUSE

The possibility exists of reusing the exhausted dyebath for subsequent dyeings, thus making use of the auxiliary chemicals for more than one cycle of dyeing. This results in production cost savings and also decreases the volume of wastewater and quantity of pollutants discharged. To realize this possibility of dyebath reuse, a method was needed for analyzing the exhausted dyebath to determine the quantities of dyestuffs remaining and thereby compute the add quantities for the next dyeing.

Much of the work in developing the dyebath analytical techniques and reconstitution methods was performed at the School of Textile Engineering at the Georgia Institute of Technology in the 1970's (References 2, 3 and 4).

The work described herein expands upon the work conducted previously on dyebath reconstitution and reuse in the following ways:

1. It examines the application of dyebath reuse at a mill that is fairly typical of many dyehouses, yet is not a "perfect" candidate for this technology.

- Dye formulations had to be modified to use a smaller number of dyestuffs before reconstitution became technically feasible.

- Quality control requirements are strict at this mill, thus posing a stiff test of the ability of dyebath reuse to produce acceptable dyeings.

- Overflow rinsing is typically used at this mill, thereby affecting not only the dyebath analysis/reconstitution methods, but also affecting the economics of dyebath reuse.

2. It presents the first development of environmental data for this wastewater recycle/reuse technology, thus allowing the environmental benefits of dyebath reuse to be quantified.

3. It updates the equipment used in dyebath analysis to include a modern desk-top computer, a commercially available interface for the spectrophotometer/computer, and software written in the BASIC computer language to allow for greater comprehension and adaptability to a variety of desk-top computers. The required equipment and programs are described in Reference 5.

In addition, this project included the development of a detailed user's manual that examines the techniques used in the development and full-scale testing of the technology at this mill. These techniques can be directly applied by other mills wishing to examine the feasibility of dyebath reuse (Reference 5).

DYEBATH REUSE STUDIES

In order to develop information on the full-scale implementation and cost of dyebath reconstitution and reuse, a demonstration of the technology was performed at a textile mill. A carpet mill owned and operated by Bigelow-Sanford, Inc. was selected for the full-scale evaluation. The mill performs atmospheric batch dyeing primarily of nylon carpet, discharging about 1 million gallons per day of wastewater to the municipal collection system.

Two popular, large-volume carpet styles were selected for dyeing using dyebath reuse procedures. The dye recipes for these styles had recently been reformulated to utilize a small number of dyestuffs. Many of the different shades now have recipes containing varying amounts of the same three dyestuffs. This is an essential step in implementing dyebath reuse since the residual dyes in the dyebath from the just completed dyeing must be the same ones that are to be used in dyeing the next shade.

Dyebath analyses were conducted using a visible-light spectrophotometer and a desk-top computer. Dyestuff absorbance coefficients were first determined in the laboratory at various wavelengths of light for each of the dyestuffs. These coefficients are the k-values in the Lambert-Beer equation:

$$A = kC$$

where A = absorbance of the dyestuff,
and C = concentration of the dyestuff.

These values were then used to analyze exhausted dyebaths to determine the amounts of dyestuffs that remained at the end of a dyeing.

Software was developed for the desk-top computer to allow it to perform all the calculations needed to determine how much dye and auxiliary chemicals remained in a used dyebath, and how much had to be added to perform the next dyeing. In this way, the actual procedures needed to reuse a dyebath could be carried out in only a few minutes by dyehouse personnel.

A detailed and very accurate analysis of the auxiliary chemical quantities remaining in the dyebath is not needed nor would it be easy to obtain. Instead, the computer calculated amounts of auxiliary chemicals required to be added to reconstitute the dyebath by using a simple mass balance equation, based on the volume of dyebath reused, the volume of cooling water added, and assumptions as to the degree of exhaustion of auxiliary chemicals. Certain auxiliary chemicals will completely exhaust or evaporate during dyeing, and the percent makeup will thus be 100 percent. Examples are defoamers, volatile chemicals, and finishes that adsorb onto the textile fibers.

Bench-Scale Tests

The actual dyebath reuse study consisted of 26 series of dyeings. Each series consisted of from 5 to 10 dyeings using the same dyebath.

The first 15 series were bench-scale dyeings. These bench-scale dyeings provided opportunities to become familiar with dyebath reuse concepts and procedures, to test the shade-matching capability of dyebath reuse, and to resolve any problems that arose, while still on a small scale. Six shades from each of the two carpet styles were selected for dyeing. For each of these shades, the dyebath was reused until a series of five dyeings was completed. This accounted for the first 12 series. The final three bench-scale series each started with a light shade and gradually progressed to dyeing darker shades as the dyebath was reused. The dyed carpet samples from these bench-scale dyeings were analyzed with a Diano/Hardy II spectrophotometer to evaluate the ability of dyebath reuse to produce acceptable shade matches.

Table 1 presents color difference data for each of the reconstituted bench-scale dyeings. The first dyeing of each shade was called the standard, since it was dyed conventionally in a fresh bath. These color differences give a quantitative measure of the uniformity of the carpet sample dyed in reconstituted baths. It should be noted that, in contrast to full-scale dyeings, no dye adds were attempted during bench- or pilot-scale trails. In full-scale dyeing, significant color differences are corrected by adding more dye to the dyebath and continuing the dyeing until the shade becomes acceptable.

A review of Table 1 shows that over 80 percent of the reconstituted dyeings had color differences from the standard of less than 3 Starlab units (approximately 6 MacAdam units). These relatively small color differences would normally be corrected in production dyeing by making a dye add. These bench-scale dyeings therefore showed that good shade matching with dyebath reconstitution and reuse was possible at this mill.

Pilot-Scale Tests

Following the success of the bench-scale dyeings, eight additional dyebath reuse series were conducted using a pilot-scale beck. The pilot-scale beck and dyeing procedures more closely resemble full-scale dyeing as compared to bench-scale dyeings. Thus, the pilot-scale dyeing would provide an opportunity to test dyebath reuse under conditions that approximate full-scale dyeing, and resolve any problems that might arise. Both single shade and multi-shade series were dyed for each carpet style.

Because the reuse of hot dyebaths could possibly cause unlevel dyeings, this aspect was studied prior to beginning reconstitution dyeings in the pilot-scale beck. Several carpet pieces were dyed using conventional procedures to determine the effect of initial dyeing temperature (temperature at which dye is added) on resultant carpet quality. Initial temperatures of 120°, 140°, 160°, and 180°F were tested. Visual inspection showed no apparent deterioration in quality at initial dyeing temperatures as high as 180°F for Style 1. Problems in levelness were noted at 180°F for Style 2 but, at 140°F and lower, no difficulties were encountered. It was thus decided to cool recycled dyebaths to 140°F or lower before reuse to avoid levelness problems.

The first pilot-scale dyebath reuse experiments used live steam for heating, but it was noted that this caused the dyebath pH to drift significantly from its initial value, resulting in poor dyestuff exhaustion. Use of steam coils for heating eliminated this problem, but resulted in insufficient mixing of the dyebath and resultant side-to-side shade variations. As a result, for all subsequent pilot-scale dyeings, live steam was used, and pH was closely monitored and maintained.

Color difference data were obtained for the pilot-scale dyeings as described previously. The results are shown in Table 2. In general, color differences from standard for all Style 1 dyeings were slightly greater than for Style 2. Also, for both styles, color differences were slightly greater for carpets dyed in reconstituted baths than for those dyed in fresh baths. Nevertheless, all but one of the reconstituted dyeings had a color difference from standard of less than 5 Starlab units.

Side-to-side color difference measurements were also taken, and similar trends were observed. Slightly better results were seen for fresh baths than for reconstituted baths, and for Style 2 dyeings than for Style 1 dyeings. Nearly 75 percent of all the reconstituted dyeings had side-to-side variations of less than 2 Starlab units.

Multishade dye series were conducted so that the shades dyed generally progressed from light to dark, although some dark-to-medium sequences were included. The resulting color differences were acceptable. Light-to-dark sequences are recommended for dyebath reuse, wherever possible. Drastic changes from a dark to light shade should be avoided.

The first and last dyeings in series 17 and 22 were tested for color fastness by standard test methods including 60-hour xenon, wet and dry crocking, bleed, and shampoo tests. Neither carpet style was affected in its fastness properties after five dyeings in the same dye liquor.

In summary, the results of the pilot-scale dyeings again showed that acceptable product quality was attainable with dyebath reconstitution and reuse. As a result, preparations for full-scale dyebath reconstitution and reuse trials were started.

Full-Scale Demonstration

A week-long plant demonstration of dyebath reuse was conducted at Bigelow's Summerville, Georgia, mill. The principal objective of full-scale reconstitution trials at the mill was to demonstrate this reuse method's technical feasibility. The mill demonstration would allow any problems that might develop at full-scale to be identified and resolved.

Another important objective of this effort was to collect water, chemical, and energy savings data associated with dyebath reconstitution. Environmental data on pollutant reductions due to dyebath reconstitution were not available elsewhere, and so these trials were an opportunity to obtain these data.

The first problem to be confronted in attempting to perform full-scale reconstitution dyeings at the mill was to determine the logistics of dyebath reuse. Three general approaches were considered:

1. reconstitute dyebath in-situ following hot-pull and separate rinsing of dyed carpet;

2. transfer exhausted dyebath to a holding tank, rinse and pull carpet in normal fashion, and return dyebath to beck for next dyeing; and

3. transfer exhausted dyebath to an empty, adjacent dyebeck for reuse.

For the purposes of a 1-week demonstration, the third approach was the simplest and most economical alternative. In a permanent installation, the first or second approach would normally be used.

Three adjacent becks with capacities of approximately 7,000 gallons each were selected for these trials. There were several important considerations in developing a system to transfer the exhausted dyebaths from one beck to another:

- the temperature of the dyebath to be transferred might be as high as 140°F;

- o the dyebath transfer had to be accomplished relatively quickly; and

- o the volume of dyebath transferred had to be known.

To satisfy these conditions, a temporary pump and piping arrangement was set up for the demonstration as shown in Figure 1.

At the end of a dyeing, the exhausted dyebath was pumped to an adjacent beck already loaded with carpet for the next dyeing. The dyed carpet in the first beck was then rinsed and pulled in the normal fashion. Meanwhile, a sample of the exhausted dyebath was analyzed, and the computer quickly printed out the amounts of dyes and chemicals to add for the next dyeing.

The carpet styles and shades used in these full-scale trials were selected at the beginning of the 1-week demonstration from scheduled production for that period. With the exception of the procedural changes necessary to physically perform dyebath reconstitution, all prior and subsequent dyehouse activities relative to these dyeings were unchanged. They were treated as production runs by all mill personnel and, accordingly, did not receive any more or any less attention during the inspection process than conventionally dyed production. The success of these dyeings was to depend upon whether the various post-dyeing inspections resulted in their being shipped as first quality production without the need for redyes. No quantitative shade matching measurements were made. Based on these criteria, all dyeings were successful. Table 3 summarizes the full-scale dyebath results. The dyeing problems that occurred in series 24 were attributed to a yarn lot change rather than any problems caused by dyebath reuse.

One of the incentives for dyebath reuse is the savings in water, energy, and auxiliary chemical usage. Their use was closely monitored during the reconstituion series. Table 4 summarizes the savings that occurred due to dyebath reuse. Water and chemical savings range, for the most part, from 25 to 50 percent of normal usage. Dyestuff savings were minimal, and are not listed on the table. Defoamer usage was the same in reuse dyeings as in conventional dyeings; i.e., all defoamer was assumed to have evaporated in a dye cycle.

These full-scale experiments showed that the ease of obtaining satisfactory dyeings with reconstituted baths was comparable if not superior to that of conventional dyeing procedures. The numbers of both adds and redyes were within the mill's typical frequency for these styles. The strict quality control standards of this mill were not an impediment to dyebath reuse.

The major problem encountered with full-scale dyebath reconstitution was that of pH control. Several pH adjustments of reconstituted dyebaths by monosodium phosphate (MSP) or trisodium phosphate (TSP) addition were required early in the dye series, especially with Style 1 carpet. However, as experience was gained with the behavior of these pH control agents and/or the recycled dyebath became more buffered, no adjustments were required after addition of normal makeup auxiliary chemical quantities. Improved bath control may even

be realized through reconstitution. This is because the effects of pH and chlorine variations in incoming source water are lessened, resulting in more uniform dyebaths.

In spite of the success of these dyeings, there are some aspects of the reconstitution procedure used here that can be evaluated more fully. Maximizing the reuse of dyes and chemicals by minimizing the amount of cooling, and thus diluting, water should be further investigated. Since this will also affect the temperature of the recycled dyebath, the effects on product quality must be closely watched. These aspects were not fully evaluated because the reuse procedures used in these trials were developed to emulate as closely as possible the mill's conventional dyeing procedures. This approach was adopted to minimize the number of variables between conventional dyeings and reconstituted dyeings. However, these modifications should be explored by the mill if dyebath reconstitution and reuse is implemented full-scale.

ENVIRONMENTAL BENEFITS

Wastewater samples were collected both during the pilot-scale and full-scale dyeings. The results of the full-scale data are presented below to characterize the potential environmental benefits of dyebath reuse.

Pollutant	Percent Reduction in Discharge	
	Series #25	Series #26
Flow (gal./lb)	24	34
BOD	13	33
COD	32	33
TSS	47	0
TDS	25	43
Phenolics	0	0
Total-P	28	44

The concentrations of various pollutants in the dyebath increased as the dyebath was reused. This is suspected to be due to the buildup of yarn finishes that are removed from the carpet during dyeing. Despite these higher concentrations, the net effect of dyebath reuse is to reduce the mass of pollutants actually discharged, as compared to conventional dyeing. This net reduction is due to the smaller amounts of auxiliary dyeing chemicals needed to perform reuse dyeings. The lack of suspended solids reduction in test series #26 is an exception to this observation and cannot be explained.

The larger reductions in wastewater volume and pollutant discharge in Series 26, as compared to Series 25, were due to attempts to reduce the volume of overflow cooling water used in the dye cycle. Less cooling water results in less dilution of the dyebath. Consequently, smaller amounts of auxiliary chemicals are needed to reconstitute the dyebath for reuse. This results in both water use/discharge reductions and pollutant discharge reductions. Further optimization in this area will result in even greater environmental benefits.

COSTS

The capital cost of permanently installing dyebath reuse at two of the mill's dyebecks is about $80,000. This includes a pump; a 6,000

gallon dyebath storage tank; associated piping, valves, and controls; and the dyebath analysis equipment and computer. This two-beck system is illustrated in Figure 2.

Yearly operating costs are estimated to be $5,000. Yearly savings, as shown in Table 5, are $60,000 for two becks. This results in a payback period of about 1.5 years. The prospects for reducing the payback period even further are good. Many areas exist for optimizing the dyebath reuse process, thereby increasing the chemical and energy savings.

OUTLOOK FOR USE IN INDUSTRY

As noted above, batch dyeing accounts for half of the total amount of textile dyeing. Due to the higher water and chemical usage of batch dyeing, well over half of the wastewater volume and pollutant loading from dyeing results from batch dyeing operations.

In certain industry sectors, dyeing is performed almost exclusively by batch operations, and thus the mills in these sectors can be regarded as potential users of dyebath reuse technology. These sectors include knit fabric finishing, hosiery finishing, and yarn finishing. A large amount of carpet dyeing is still performed in batch operations, although there is a trend toward production of more continuous dyed/printed carpet. Most large woven fabric finishing mills employ continuous dyeing, though some smaller mills still have significant batch dyeing operations. Overall, a large number of mills can potentially adopt this recycle technology.

Dyebath reuse has been tested or demonstrated with a wide variety of products and textile fibers. Examples include nylon hosiery and carpet; polyester fabric, carpet, and yarn; acrylic yarn; and cotton fabric. Dyestuff classes that have been tested or demonstrated include acid, basic, direct, disperse, and reactive.

At many mills, not all production will be amenable to dyeing by dyebath reuse. However, even the conversion of a few machines to this recycle technology will have substantial cost and environmental benefits. A mill that is ideally suited to employ dyebath reuse technology will generally only dedicate half of its dye machines to reuse dyeing. This is to ensure that flexibility in production is maintained.

CONCLUSIONS

This project demonstrated the technical feasibility of batch dyebath reconstitution and reuse at a carpet mill. It demonstrated how several technical problems common to a wide variety of mills were overcome. These problems included selecting product styles and shades that can be incorporated in a dyebath reuse scheme; reformulating dye recipes to use a single group of dyestuffs to dye many shades; demonstrating that dyebath reuse can be accomplished on a portion of production within the normal production schedule; producing high-quality product with recycled dyebaths; and adapting the dyebath reuse procedures to conform to the mill's standard dyeing procedures, including such considerations as initial dyebath temperature and the use of overflow cooling.

Environmental benefits are significant, even when dyebath reuse is practiced in a non-optimal fashion. Pollutant and water use reductions of 25 to 50 percent were observed. Environmental benefits are maximized when dilution of the dyebath through steam condensation and overflow cooling is kept to a minimum.

Dyebath reuse is economically attractive, even when practiced in a non-optimal fashion. A payback period of 1.5 years was determined for this mill. Again, economic benefits are maximized when dilution of the dyebath is minimized.

Based on these results and estimates, this mill is making plans to acquire, install, and modify necessary equipment in the near future to enable reconstitution to be implemented at certain becks.

Because of the large amount of batch dyeing performed in the industry, and the low capital cost and attractive economics of dyebath reuse, this wastewater recycle/reuse technology can be expected to grow in use. Specific areas for use include knit fabric dyers, carpet dyers, and yarn dyers. Larger hosiery mills may also find dyebath reuse advantageous.

UNIT CONVERSION TABLE

1 gallon = 0.003785 m^3
1 pound = 0.4536 kg
1 Btu = 1.055 kJ
°F = °C x 9/5 + 32
°C = (°F-32) x 5/9

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TABLE 1
BENCH-SCALE SHADE MATCHING RESULTS

Series Number	Shade	Average Color Differences (Starlab Units) Bath #1	Bath #2	Bath #3	Bath #4	Bath #5	Bath #6
1	105	Std	0.78	2.16	1.55	2.52	--
2	106	Std	0.63	0.41	0.89	0.54	--
3	103	Std	5.86	3.11	3.42	3.20	--
3A	103	Std	2.29	3.13	3.74	3.32	--
4	104	Std	1.81	5.11	1.98	1.83	--
5	102	Std	0.86	1.32	2.37	--	--
6	101	Std	1.10	2.08	1.28	1.60	--
7	205	Std	0.87	1.73	1.01	1.57	--
8	206	Std	1.21	1.35	1.42	1.53	--
9	204	Std	0.58	0.52	0.92	0.60	--
10	202	Std	0.91	--	--	--	--
10A	202	--	--	1.15	1.30	0.99	--
11	203	Std	0.09	0.67	0.34	1.58	--
12	201	Std	2.05	2.46	3.06	2.63	--
13	Multi	0.42	1.17	5.65	2.89	4.47	3.86
14	Multi	0.95	1.06	1.98	2.37	N/A	--
15	Multi	1.05	2.60	1.75	2.10	1.77	--

N/A - Data not available

TABLE 2
PILOT-SCALE SHADE MATCHING AND LEVELNESS RESULTS

Shade Matching

Series Number	Carpet Style	Shade	Color Difference From Standard (Starlab Units) Bath #1	Bath #2	Bath #3	Bath #4	Bath #5	Bath #6	Bath #7	Bath #8	Bath #9	Bath #10
17	1	103	3.08	4.11	4.64	4.28	3.41	--	--	--	--	--
18	1	101	1.10	2.43	3.97	1.34	1.52	--	--	--	--	--
19	1	Multi	1.50	1.78	1.54	1.22	1.11	5.53	4.00	3.56	3.85	4.51
20	2	201	0.83	1.17	0.93	N/A	2.69	N/A	--	--	--	--
21	2	203	0.45	0.68	0.69	N/A	1.50	--	--	--	--	--
22	2	206	1.90	1.83	1.74	2.62	2.40	--	--	--	--	--
23	2	Multi	1.66	1.04	3.78	3.80	1.66	1.21	2.75	2.50	3.10	2.95

Levelness

Series Number	Carpet Style	Shade	Side-to-Side Color Difference (Starlab Units) Bath #1	Bath #2	Bath #3	Bath #4	Bath #5	Bath #6	Bath #7	Bath #8	Bath #9	Bath #10
17	1	103	1.00	4.69	6.69	5.02	0.62	--	--	--	--	--
18	1	101	1.58	N/A	7.66	2.34	N/A	--	--	--	--	--
19	1	Multi	0.64	1.59	2.98	1.83	1.70	0.73	1.50	1.07	0.96	1.07
20	2	201	0.80	0.94	0.70	N/A	1.01	N/A	--	--	--	--
21	2	203	0.53	0.68	0.90	N/A	0.48	--	--	--	--	--
22	2	206	1.55	1.60	0.87	0.79	0.99	--	--	--	--	--
23	2	Multi	0.86	0.90	1.81	1.88	1.76	1.72	1.49	4.08	0.76	2.00

N/A - Data not available.

TABLE 3
FULL-SCALE DYEING DYEBATH SUMMARY

Series Number	Dyebath Number	Shade	Shade Description	Number of Adds	Add Summary *			Cooling Summary		Initial Dyebath Temp, °F	Remarks
					Add 1	Add 2	Add 3	C.W. Gallons	Cooling End Temp, °F		
24	1	111	Lt. Yellow	0	--	--	--			68	--
24	2	111	Lt. Yellow	4	D	D	D	2,700	148	108	a,b,c
24	3	101	Lt. Brown	3	D,B	D	D	2,700	146	116	c,d
25	1	101	Lt. Brown	1	D	--	--	--	--	68	
25	2	112	Lt. Golden Br.	1	D	--	--	2,700	138	95	
25	3	112	Lt. Golden Br.	1	D,L	--	--	4,500	136	105	
25	4	103	Med. Gray	2	D,L	D,L,B	--	4,500	120	105	
25	5	113	Med. Plum	2	L	D	--	4,500	138	100	
25	6	113	Med. Plum	0	--	--	--	4,500	124	105	
26	1	211	Pale Yellow	3	L,B	B	D,L,B	--	--	68	
26	2	211	Pale Yellow	2	D	D	--	5,400	130	105	
26	3	212	Smoke	1	D,L	--	--	3,600	120	92	
26	4	212	Smoke	1	D,L	--	--	4,500	133	102	
26	5	213	Buff	1	D	--	--	2,700	137	105	
26	6	214	Beige	2	D	D	--	2,250	134	104	e
26	7	215	Bronze	0	--	--	--	3,600	142	105	
26	8	215	Bronze	1	L	--	--	1,800	140	93	
26	9	216	Tan	0	--	--	--	1,800	138	103	
26	10	217	Royal Blue	0	--	--	--	1,800	144	116	
								--	--		

*Identifies addition of dyes (D) and/or leveler (L), and if add carried out at boil (B).

(continued)

TABLE 3 (continued)

Remarks

a - A fourth add consisting of addition of leveler and dyeing at the boil was also performed.
b - The two carpets removed from this dyebath after the fourth add subsequently needed to be redyed. These were the only redyes required out of 32 reconstituted dyeings (16 dyebaths).
c - A yarn lot change was subsequently determined as the cause of difficulties in this dyeing.
d - Dyebath dropped after first add and one of two rolls removed; due to unlevel dyeing, remaining roll required two more adds until acceptable. Reuse Series Number 24 was terminated. See Remark "c".
e - Dyeing accidently performed at boil; adds performed at 180°F.

TABLE 4
WATER, ENERGY, AND CHEMICAL SAVINGS

Dyeing	Water Savings (gal.)	Energy Savings (10^6 Btu)	Chemical Savings			
			M.S.P. (lb)	T.S.P. (lb)	Sequesterant (lb)	Leveler (gal.)
25-1	2,400	0.0	0	0	0	0
25-2	5,000	1.33	-11	19	5.5	3.0
25-3	5,200	1.83	9	14	5	1.5
25-4	4,000	1.83	4	14	5	1.5
25-5	3,600	1.58	-1	14	5	-0.5
25-6	5,300	1.83	9	14	5	1.5
Totals for Series 25	25,500	8.40	10	75	25.5	7.0
26-1	100	0.0	0	0	0	0
26-2	4,700	1.78	-1	11	5	2.5
26-3	4,700	1.15	6	12	5.5	2
26-4	7,000	1.63	0	13	5	1
26-5	7,650	1.78	3	11	6	2
26-6	6,300	1.73	3	11	6	2
26-7	6,500	1.78	2	12	5	1
26-8	6,500	1.20	2	14	6	0
26-9	8,100	1.68	4	14	6.5	3
26-10	7,900	2.30	4	15	6.5	2
Totals for Series 26	59,450	15.03	23	113	51.5	15.5

TABLE 5

FULL-SCALE DYEBATH REUSE
COST SAVINGS

Series 26 (Carpet Style 2 : 10 dyeings)

Cost Item	Savings from Dyeing Quantity	Savings from Dyeing Dollars	Percent Savings vs. Normal Dyeing
Dyes -			1
Orange	0.044 lb	$0.10	
Red	0.015 lb	0.10	
Blue	0.014 lb	0.10	
Chemicals -			35
MSP	23 lb	12.80	
TSP	113 lb	36.70	
Sequesterant	51.5 lb	21.60	
Leveler	15.5 gal.	114.70	
Defoamer	0 gal.	0.00	
Water/Sewer	59,500 gal.	47.00	36
Energy (Steam)	19,500 lb	53.30	Not estimated
	Total	$286.40	

Average per cycle savings = $28.60 (based on 10 cycles)

Yearly Savings = $25/cycle x 1,200 dyeings/beck/year x 2 becks
= $60,000/year

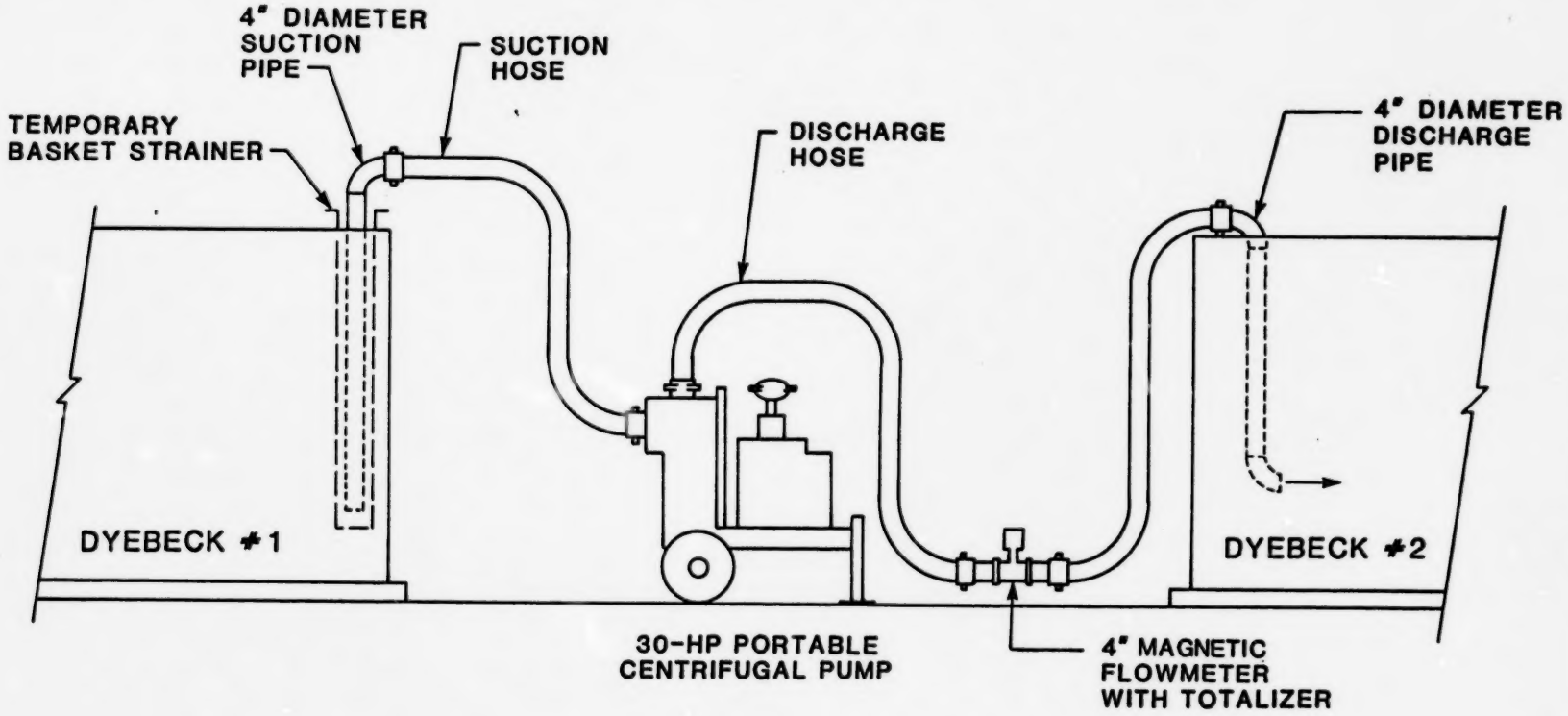

FIGURE 1 TEMPORARY DYEBATH TRANSFER SYSTEM

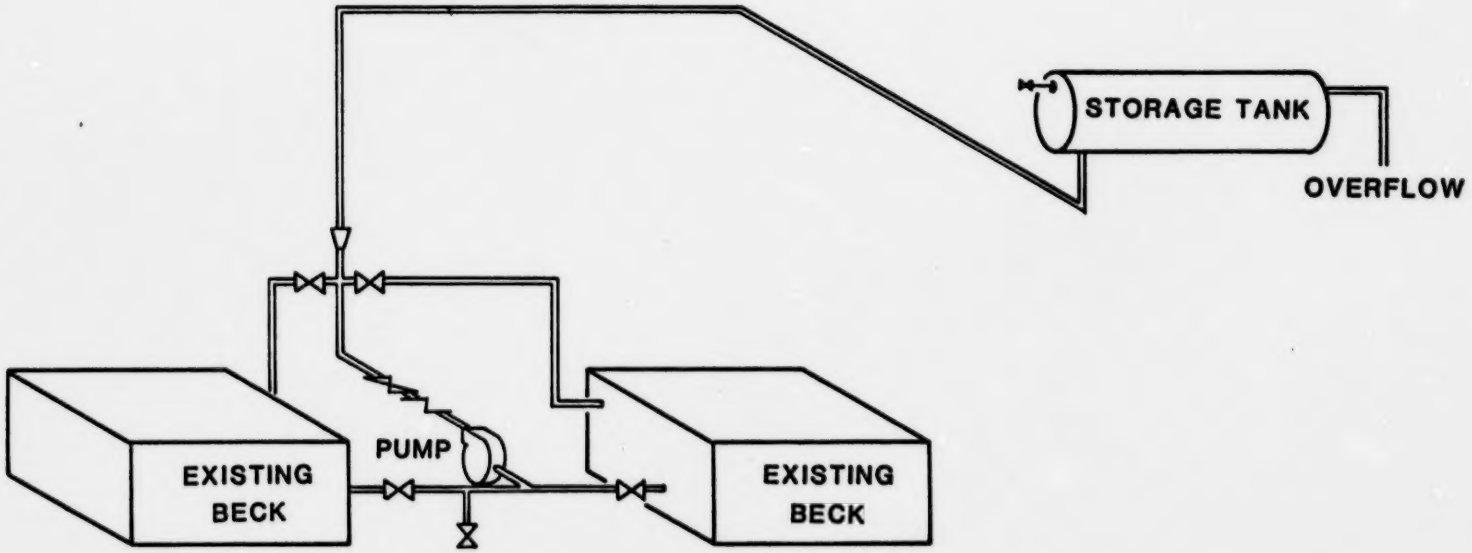

FIGURE 2 PRELIMINARY PIPING DESIGN